CHAPTER 7

Dose-response effects of a Web-based physical activity intervention on body composition and metabolic health in inactive older adults: additional analyses of a randomized controlled trial

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Abstract

Background. Low physical activity (PA) is a major risk factor for several age-related diseases. Recently, we showed in a randomized controlled trial that a 12-weeks Web-based intervention (Philips DirectLife) aiming to increase physical activity was effective in increasing physical activity levels and metabolic health in an inactive population aged 60-70 years. Understanding of how many participants successfully reached the PA target and what the effects in these individuals were, can contribute to better results of such interventions in the future.

Methods. Among 235 participants of the AGO study, a randomized controlled trial, we assessed the effects of the intervention on metabolism in those who had successfully reached the PA target compared with the entire intervention group. Furthermore we studied the dose-response effect of increase in PA on metabolic outcome within the intervention group.

Results. Of the intervention group, 50 out of 119 (42%) participants successfully reached the PA target. This group showed markedly higher effects compared to the entire intervention group, with greater decreases in body weight (2.74 vs. 1.49 kg), waist circumference (3.74 vs. 2.33 cm), HOMA-index (0.23 vs. 0.20) and in cholesterol/HDL-ratio (0.39 vs. 0.20) and Framingham risk score (0.90 vs. 0.54 %). The dose-response analysis showed that there was a significant association of increase in minutes spent in moderate-to-vigorous activity with weight loss (p=0.004), BMI reduction (p=0.02), waist circumference reduction (p=0.03), HDL-cholesterol lowering (p=0.007) and cholesterol/HDL ratio lowering (p=0.02)

Conclusions. Of the intervention group, 42% had reached the daily PA end goal, which was associated with a markedly better effect on body composition and metabolic health compared to the effect in the entire intervention group. Findings demonstrate the large potential of Web-based interventions for improving health in the aging population by increasing PA, with likely improvement still to be sought in increasing the proportion of the population reaching the targeted goal.

CHAPTER 7. DOSE-RESPONSE EFFECTS OF A WEB-BASED PHYSICAL ACTIVITY INTERVENTION

Introduction

Insufficient physical activity is a major risk factor for several lifestyle- and age-related diagnoses including cardiovascular disease, diabetes mellitus and cognitive decline (5; 14; 15; 19; 20; 22; 28). Intervention studies directed at increasing physical activity in older people have shown to be effective in improving metabolic health in older populations (6; 9). However, most of the physical activity interventions have used face-to-face communication, making them costly, time-consuming, thus hampering the potential of implementation as preventive programs at a larger scale. There is a need for new and effective intervention strategies that allow for large scale implementation.

Recently, we performed the Actief en Gezond Oud (AGO) study, a randomized controlled trial into the effect of a 3-month Web-based intervention program targeted at improving physical activity in inactive older adults (26). The intervention program (Philips DirectLife) consisted of the use of an accelerometer, online feedback and coaching over the internet. Results showed that the intervention was effective in increasing objectively measured physical activity and in improving metabolic health in inactive older adults in the total study population. However, this intention to treat analysis did not include individual analyses of treatment success. Understanding of what proportion of the study population successfully reached the PA target and what the effects of the intervention were in these individuals, can contribute to better results of such interventions, for instance by targeting specific populations, or adjusting the target PA level (10; 13).

In the present paper we performed additional analyses in the AGO study. First, we analysed what proportion of participants successfully reached the programs PA target. Second, we analysed the effect on metabolism of the intervention in those participants successfully reaching PA target. Third, we performed a dose-response analysis of the increase in physical activity in association with metabolic outcomes among all participants in the intervention group.

Methods

Study design and participants

All analyses of this paper were performed with data obtained from an previously reported randomized controlled trial into the effects of a 3-months Web-based intervention program targeted at enhancing levels of daily physical activity in inactive older adults: The Actief en Gezond Oud (AGO) study (26). In short this study recruited participants aged 60 to 70 years from the region of Leiden, The Netherlands through advertisement in local newspapers and press notification, directing participants motivated to increase physical activity to the study website, where they completed an online questionnaire. Inclusion criteria included 1) age between 60 and 70 years, 2) possession of and knowledge how to use a personal computer. Exclusion criteria included 1) active lifestyle as assessed by the GPPAQ (see below), 2) history of diabetes or use of glucose lowering medication, 3) physical inability or medical contra-indication to increase physical activity level. The presence of an inactive lifestyle was then assessed by a self-report physical activity questionnaire: i.e. the general practice physical activity questionnaire, GPPAQ (2). The GPPAQ asks questions with respect to average physical activity of the participant and categorizes people in four levels of physical activity. We excluded participants in the highest level of physical activity, which corresponded to performing more than 3 hours of self-reported exercise and cycling combined weekly. At the baseline visit participants were randomly assigned to the intervention group or a waiting list control group by the study physician or research nurse. Randomization was performed by a computerized program for intervention versus waiting list control in a ratio of 1:1, with a block size of 12. Stratification was performed by gender. Concealment of treatment allocation was ensured by randomizing at the end of the first study visit, after all baseline measurements and instructions at the study center were completed. The study was approved by the medical ethical committee of Leiden University Medical Center, The Netherlands. An independent physician was available for questions regarding study information. Trial registration: Dutch Trial Registry (www.trialregister.nl), NTR 3045

Intervention

Participants in the intervention group received a commercially available Web-based physical activity program (DirectLife, Philips, Consumer Lifestyle, Amsterdam) directed at increasing daily physical activity. The DirectLife program is based on

established health behavior change models (18; 24) and takes into account the individual's current daily physical activity level, and subsequently provides a personal goal. Briefly, DirectLife consists of three elements: 1) an accelerometer-based physical activity monitor, 2) a personal website, and 3) a personal e-coach, who provides regular updates of the individual's physical activity status by e-mail and gives who advice to increase daily physical activities. By means of these elements, the program aims to increase awareness about one's own physical activity behavior, to give feedback on recent actual physical activity, and to provide support to make sustainable changes in physical activity behavior. The activity monitor of DirectLife is based on the Tracmor tri-axial accelerometer, and has been validated against doubly labeled water for the estimation of total 24 hour energy expenditure (4). The DirectLife monitor is the consumer version of the Tracmor accelerometer. Intervention group participants received the program, including the accelerometer, directly after randomization at the first study visit. By e-mail they then received a link for registration and access to the Web-based program. Participants were instructed to continuously wear the activity monitor throughout the day to measure daily physical activity. Data were uploaded through an Internet connection to the database of the commercial provider on a regular base, ranging between daily and once per 14 days . After an initial eight-day "assessment period" starting one week after the study visit, in which the current level of daily physical activity was measured, a target was set to increase the level of daily physical activity during a 12-week Web-based interactive coaching program. Participants were given a target for daily physical activity, which increased weekly, and data from the accelerometer were used for daily feedback. Coaching included general recommendations on physical activities from real-life coaches and were available for further questions and advice by e-mail correspondence. All participants were in contact with one of the e-coaches available for the DirectLife program during the entire study period. These coaches were actual persons in contact with the participant through the intervention website or though e-mail. The control group was placed on a 3-months waiting list after which they received access to the intervention program, at the end of the study. No specific instructions regarding daily physical activity were given.

Measurements

Enrollment and follow-up took place from November 2011 to August 2012.

Baseline questionnaire

In preparation of the first visit to the study center, all participants completed a Web-

delivered questionnaire on education, smoking status and medical history, including medication use. Education was categorized as low (primary education and lower vocational education), intermediate (secondary education and intermediate vocational education) or high (high vocational education and university).

Physical activity outcome

At baseline and 3-months follow up, daily physical activity was measured during seven days following the visit at the study center, using an wrist worn tri-axial accelerometer (GeneActiv, Kimbolton, Cambs, UK). Wearing of the GeneActive monitors started on a random weekday, and were returned after seven days by standard mail. We chose to assess the primary outcome using accelerometers other than the one included in the intervention program to avoid interpretation of the intervention as an outcome. The GeneActive monitors were worn 24-hours per day on the right wrist. The GeneActiv wrist accelerometer provides a simple summary statistic of total physical activity counts that has been validated for measuring daily physical activity against doubly-labeled water (23). As a derivative outcome, we calculated the minutes per day spent in moderate-to-vigorous intensity physical activity (MVPA) from the wrist accelerometer, which has been validated against indirect calorimetry (7). Measurement frequency was set at 85.7 Hz and raw acceleration values in "g" were recorded continuously on each axis over seven consecutive days. Further details on data processing can be found elsewhere (26). Outcome assessment was done by an independent researcher who was blind to study arm allocation.

Other outcomes

Body height was measured without shoes using a stadiometer. Body weight was assessed at both visits without shoes using a scale. Waist circumference was obtained in a standing position halfway between the anterior superior iliac spine and the lower rib. Hip circumference was measured halfway between the trochanter major and the iliac crest.

Lean body mass and body fat percentage were assessed by bio-electrical impedance (BIA) analysis (Biostat 1500, Euromedix, Leuven, Belgium). Blood pressure was measured twice at each visit using a hand-held sphygmomanometer after five minutes of lying down. The mean of the two consecutive measurements was used. Pulse rate was measured by hand at the wrist after at least five minutes of lying down. Grip strength was measured to the nearest kilogram three times using a Jamar handheld dynamometer (Sammons Preston, Inc., Bolingbrook, IL, USA) with the dominant hand. The highest value was used for analysis. Framingham risk scores were calculated using NIH criteria (1).

Biochemical assessments

Fasting blood samples were drawn from each participant at both visits in the morning. Samples were transferred to the lab within two hours, aliquotted and frozen at -80C. All serum measurements were performed in one batch after completion of the entire study with fully automated equipment. Fasting glucose, cholesterol, HDL-cholesterol and triglyceride levels were determined using the Modular P2 analyzer (Roche, Almere, the Netherlands), fasting serum insulin using immunoassay by Immulite 2500 (DPC, Los Angeles, CA, USA). Glycated hemoglobin was determined by high performance liquid chromatography (Primus Ultra2, Trinity Biotech Company, Kansas City, MO, USA). C-reactive protein (hsCRP) was determined using a high-sensitive immunoassay (COBAS integra, Roche, IN, USA). Low density lipoprotein (LDL) cholesterol was calculated using the Friedewald formula in participants without hypertriglyceridemia (8).

End point of the DirectLife intervention

To assess the potential effects of the Web-based intervention, a subgroup was created from the intervention group including participants successful in reaching the targeted increase in physical activity indicated by the intervention program. A participant was defined as successful when participants successfully had reached their personal end goal for at least two weeks in the last three weeks of the DirectLife program.

Personal end goals were set by DirectLife as the absolute increase in physical activity compared to the individual's baseline assessment data. For the whole group, this corresponded to a mean increase of approximately 10% in daily physical activity. All participants were given the option to minimally increase or decrease their personal end goal.

Tertiles for dose-response relationship

To further explore the effect of physical activity the entire intervention group was divided in tertiles based on the change in minutes spent in moderate-to-vigorous activity. Because of technical errors, data on moderate to vigorous activity count were not available for 11 of the 119 intervention group participants (9%), resulting in

three tertiles with 36 participants. The lowest tertile showed on average a decrease of 6.75 (SE 1.37) minutes spent in moderate to vigorous activity. The middle tertile showed on average an increase of 5.91 (SE 0.56) minutes and the highest tertile showed on average an increase of 34.3 (SE 3.59) minutes spent in moderate to vigorous activity.

Statistical analyses

Baseline differences between the successful participants and the control group, and between the entire intervention group and the control group were calculated using a t test for continous data, a Mann-Whitney analysis for skewed data and a Chi-squared test for categorical data. Differences between baseline and follow-up within groups were tested using a paired sample Student t test of the means. Differences between groups were calculated using linear regression and were adjusted for age and gender. All analyses were performed with SPSS version 20.0 (IBM, Armonk, NY, USA). Statistical significance was accepted at $P < 0.05$.

Results

A detailed flow of recruitment and inclusion was outlined elsewhere [26]. In short, a total number of 631 subjects responded to the newspaper advertisement, of whom 344 fulfilled the selection criteria. In total, 235 participants were randomized into the study: 119 in the intervention group and 116 in the control group. Of the 235 randomized participants, 226 (96%) completed the trial.

Of the intervention group, 50 participants (42%) successfully reached their personal physical activity end goal ('successful' participants). Of the 69 who were not defined as successful, 18 did not finish the DirectLife program (15% of intervention group) and 51 did not reach his/her personal end goal (43% of intervention group).

Table 1 shows the baseline characteristics of the entire intervention group (n=119) and the successful participants (n=50) and both groups were compared with the entire control group (n=116). Male participants tended to be more likely to successfully reach their personal end goal for DirectLife, compared to female participants. Of the successful participants 26% was female, compared to 40% in the entire intervention group. In line with a difference in gender-distribution, the

Table 1. Baseline characteristic of control group, total intervention group and successful participants

	Control group	Intervention group			
	Total control group (n=116)	Total intervention group (n=119)	P-value for total intervention vs. total control group	Successful participants (n=50)	P-value for successful participants vs. total control group
Demographics (n,%)					
Female sex	49 (42.2)	47 (39.5)	0.67	13 (26.0)	**0.047**
Age, yrs (mean, SD)	64.9 (2.8)	64.7 (3.0)	0.61	64.6 (2.8)	0.63
Clinical parameters (mean, SD)					
Height (cm)	172.1 (9.3)	173.6 (9.9)	0.25	175.7 (9.6)	**0.024**
Weight (kg)	86.3 (15.8)	87.4 (15.8)	0.61	87.6 (15.6)	0.64
BMI (kg/m²)	29.1 (4.7)	28.9 (4.7)	0.84	28.2 (3.7)	0.25
Waist circumference (cm)	101.4 (12.3)	102.3 (13.1)	0.56	102.1 (12.2)	0.74
Fat Percentage (%)	36.4 (8.1)	36.5 (7.6)	0.95	34.5 (6.3)	0.11
Cardiovascular disease risk					
Framingham 10 year CVD risk (%)	11.3 (7.5)	11.9 (7.2)	0.50	13.3 (7.5)	0.10
Physical activity (mean, SD)					
5-day moderate to vigorous activity (min/day) (median, IQR)	14.5 (8.2-32.5)	16.8 (7.8-26.4)	0.43	20.0 (9.2-27.5)	0.97
Biochemistry (mean, SD)					
Fasting venous glucose	5.7 (0.8)	5.7 (0.7)	0.94	5.6 (0.6)	0.78
Fasting insulin (mU/L) (median, IQR)	10.8 (7.0-15.8)	11.5 (8.1-16.9)	0.47	12.4 (8.0-19.8)	0.32
HbA1c (%)	5.4 (0.3)	5.4 (0.3)	0.44	5.4 (0.2)	0.72
HOMA index (median, IQR)	2.6 (1.7-4.3)	2.8 (2.0-4.3)	0.48	3.0 (2.0-5.0)	0.39
Total cholesterol	5.8 (1.0)	5.7 (1.1)	0.74	5.6 (1.1)	0.28
HDL cholesterol	1.4 (0.4)	1.5 (0.5)	0.51	1.4 (0.5)	0.93
Triglycerides (median, IQR)	1.4 (1.1-2.0)	1.5 (1.1-2.0)	0.65	1.5 (1.1-2.0)	0.99
LDL cholesterol	3.6 (0.9)	3.6 (1.0)	0.66	3.4 (1.0)	0.25
Total/HDL cholesterol ratio	4.3 (1.3)	4.2 (1.3)	0.65	4.2 (1.3)	0.70
C-reactive protein (median, IQR)	1.4 (0.8-4.1)	1.6 (0.8-3.1)	0.83	1.7 (0.7-3.8)	0.85

Data are presented as medians with interquartile range (IQR) when skewed.

P-values were calculated with t-test (continous data), Mann-Whitney (skewed data) or Chi-squared (categorical data).

average height of the successful participants was higher compared to the control group. No other significant differences between groups were found.

Table 2 shows the effects of the intervention at the follow-up for the successful participants and the entire intervention group, both compared to the control group. Here we assess the magnitude of the effects in the group of successful participants compared to the entire intervention group. Among the successful participants, time spent in moderate-to-vigorous intensity physical activity increased significantly (18.8 Min/day, standard error (SE) 3.9) compared to the entire intervention group (11.1 Min/day, SE 2.1). The successful participants lost more body weight (mean (SE) of 2.74 (0.40) kg) compared to the entire intervention group (1.49 (0.26) kg). Beneficial effects were also seen on waist circumference with a decrease of 3.74 (0.55) cm vs. 2.33 (0.36) cm in the successful participants vs. the entire intervention group. In line with the beneficial changes in body composition, significant improvements were seen in biochemical parameters in the successful participants compared to the entire intervention group (figure 1). Beneficial effects were seen for the HOMA index with decreases of (0.23 (0.06) and 0.20 (0.05), respectively, and decreases for the cholesterol/HDL-ratio (0.39 (0.11) and 0.20 (0.07). For the Framingham Risk Score a decrease was seen among the successful participants (0.90 % (0.46)) compared to 0.54% (0.33) in the entire intervention group.

Finally, we assessed the association of the increase in PA levels with metabolic outcomes in a dose response relationship. Table 3 shows the tertiles that were made based on increase in minutes spent in moderate-to-vigorous intensity physical activity, as objectively measured with the wrist worn accelerometer. At baseline, the lowest tertile tended to be the most active, and had the lowest increase in minutes spent in moderate-to-vigorous intensity physical activity but this was not significant. There were significant associations of increase in PA with decreasing body weight (p for trend = 0.004), decreasing BMI (p for trend = 0.02) and reduction in waist circumference (p for trend = 0.03). Also, those who increased physical activity most showed the highest improvement in Framingham Risk Score, highest tertile -1.28 (SE 0.76) % compared to the lowest tertile (+0.43 (SE 0.46) %, p for trend = 0.06). Also for biochemical parameters a dose-response was seen for (levels of) HDL-cholesterol, cholesterol/HDL ratio and triglycerides, but not for fasting glucose or HbA1c.

Table 2. Results for clinical parameters and glucose metabolism of successful participants compared to the total control group

	Control group (n=112)	Total intervention group (n=114)		Successful participants (n=50)	
	Mean Δ (SE)	Mean Δ (SE)	P-value between groups[1]	Mean Δ (SE)	P-value between groups[2]
Physical activity					
5-day moderate to vigorous activity (min/day)	-0.15 (1.5)	11.1 (2.1)	**<0.001**	18.8 (3.86)	**<0.001**
Clinical parameters					
Weight (kg)	-0.82 (0.21)	-1.49 (0.26)	0.051	-2.74 (0.40)	**<0.001**
BMI (kg/m²)	-0.29 (0.07)	-0.50 (0.09)	0.07	-0.91 (0.13)	**<0.001**
Waist circumference (cm)	-1.29 (0.34)	-2.33 (0.36)	**0.04**	-3.74 (0.55)	**<0.001**
Body fat (%)	-0.03 (0.24)	-0.88 (0.28)	**0.03**	-1.33 (0.34)	**0.001**
Framingham risk score (%)	-0.01 (0.31)	-0.54 (0.33)	0.25	-0.90 (0.46)	0.13
Biochemistry					
Glucose (mmol/L)	-0.13 (0.04)	-0.20 (0.05)	0.32	-0.14 (0.06)	0.77
Ln insulin (mU/L)	-0.04 (0.04)	-0.16 (0.04)	**0.04**	-0.20 (0.06)	**0.03**
HbA1c (%)	-0.01 (0.01)	-0.05 (0.01)	**0.048**	-0.05 (0.02)	0.07
Ln HOMA-index	-0.06 (0.04)	-0.20 (0.05)	**0.04**	-0.23 (0.06)	0.050
Total cholesterol (mmol/L)	-0.18 (0.05)	-0.25 (0.06)	0.42	-0.38 (0.09)	0.08
HDL-cholesterol (mmol/L)	-0.04 (0.02)	-0.008 (0.02)	0.29	0.03 (0.03)	0.07
LDL cholesterol (mmol/L)	-0.11 (0.04)	-0.17 (0.04)	0.43	-0.28 (0.07)	0.08
Cholesterol/HDL ratio	-0.05 (0.05)	-0.20 (0.07)	0.12	-0.39 (0.11)	**0.007**

P-values between groups were calculated with linear regression. All p-values were adjusted for age and sex.

1 P-value for total control group vs. total intervention group.

2 P-value for total control group vs. successful participants.

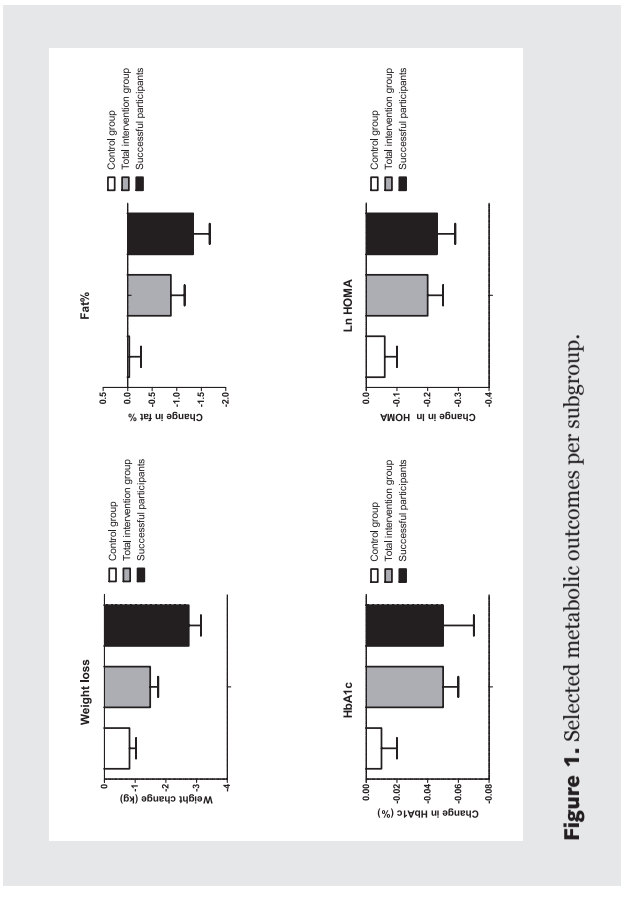

Figure 1. Selected metabolic outcomes per subgroup.

Discussion

The findings of the present study are threefold. First, 42% of the intervention group had reached the target end goal of daily physical activity. Second, we found almost doubled effects in some parameters in those who successfully had reached the targeted end goal in daily physical activity compared to the entire intervention group. Third, in the entire intervention group we found that with increasing minutes spent on physical activity, metabolic outcome improved.

So far, studies have reported different results on improving daily physical activity in different age groups through a Web-based intervention. Compared to a waiting list control group some studies reported an increase in moderate and vigorous intensity physical activity (17) or moderate intensity physical activity and walking (16) while other studies reported no significant differences in physical activity (12; 21). All of these studies used self-report questionnaires for reporting on physical activity instead of objectively measured physical activity, making it hazardous to assess who actually reached the targeted increase in PA. We report here that 42% of the entire intervention group had reached the target end goal in daily physical activity when measured objectively. To our knowledge, data on participants successfully increasing objectively measured PA as targeted are very limited. The main reason for this is that

Table 3. Dose-response relationship of D minutes spent in moderate to vigorous physical activity with endpoints

	Intervention group			P for trend	
	Low (n=36)	Middle (n=36)	High (n=36)	Crude	Adjusted[1]
Characteristics					
Mean baseline moderate-to-vigorous activity (SD)	22.5 (17.9)	17.3 (16.5)	19.0 (14.9)	0.37	0.38
Range baseline moderate-to-vigorous activity	2.4 – 87.2	0.8 – 92.0	2.4 – 62.4		
Mean D minutes moderate-to-vigorous activity (SE)	-6.75 (1.37)	5.91 (0.56)	34.27 (3.59)	**<0.001**	**<0.001**
Range D minutes moderate-to-vigorous activity	-25.8 – 1.60	1.70 – 14.2	15.8 – 117.6		
Number of successful participants	11	12	26	**<0.001**	**0.001**
Clinical parameters (Mean D, SE)					
Weight (kg)	-0.93 (0.35)	-0.64 (0.44)	-2.85 (0.51)	**0.003**	**0.004**
BMI (kg/m2)	-0.34 (0.12)	-0.23 (0.15)	-0.88 (0.17)	**0.01**	**0.02**
Waist circumference (cm)	-1.58 (0.52)	-1.92 (0.67)	-3.69 (0.72)	**0.02**	**0.03**
Fat Percentage	-0.46 (0.48)	-0.44 (0.35)	-0.94 (0.43)	0.42	0.43
Framingham risk score (%)	0.43 (0.46)	-0.78 (0.52)	-1.28 (0.76)	**0.045**	0.06
Biochemistry					
Glucose (mmol/L)	-0.23 (0.10)	-0.15 (0.09)	-0.21 (0.07)	0.90	0.94
Ln insulin (mU/L)	-0.14 (0.07)	-0.06 (0.08)	-0.26 (0.08)	0.26	0.20
HbA1c (%)	-0.04 (0.02)	-0.03 (0.02)	-0.07 (0.02)	0.17	0.20
Ln HOMA-index	-0.18 (0.08)	-0.09 (0.08)	-0.30 (0.08)	0.32	0.26
Total cholesterol (mmol/L)	-0.29 (0.08)	-0.10 (0.10)	-0.40 (0.11)	0.46	0.63
HDL-cholesterol (mmol/L)	-0.10 (0.04)	0.01 (0.04)	0.05 (0.03)	**0.004**	**0.007**
LDL cholesterol (mmol/L)	-0.19 (0.06)	-0.09 (0.08)	-0.27 (0.09)	0.49	0.61
Cholesterol/HDL ratio	0.006 (0.08)	-0.15 (0.11)	-0.48 (0.17)	**0.007**	**0.02**

P for trend was calculated with linear regression.

1 P for trend was adjusted for sex and age.

very few of the studied interventions mention an objectively measured target increase. An RCT performed among 1071 participants (mean age 53; 57% BMI≥25) studied the effect on nutrition and physical activity of a 12-week Internet program called Guide to Health (GTH-only), focusing on nutrition and physical activity, the Guide to Health program plus a series of group-based support (GTH+) and a waiting list control group. Physical activity was measured using a pedometer counting steps/day with a target for all groups to increase PA with 2142 steps/day at post-treatment compared to baseline. In the GTH+ group 41,7% increased the step count as targeted, making the GTH+ group marginally more likely to reach the step goal compared to the control group (24,4%; p=0.071). The GTH-only group showed that 35.8% successfully increased step count (27). Although the PA in this study was objectively measured in an alternate way, our results shows a similar success rate.

Our study showed many beneficial effects on metabolic health parameters, with a significant average body weight loss of 2.74 kg for the successful participants. Furthermore, our trial showed beneficial effects on metabolic health parameters also in the control group. The latter finding indicates that we have selected a motivated study population, who while on the waiting list for the intervention may have adopted other strategies to improve their level of activity. Furthermore, the finding stresses the importance of a well chosen control arm in clinical trials. Trials of other Web-based interventions on metabolic health parameters showed various results. However, most of them showed beneficial changes on metabolic health parameters. For example, the aforementioned Guide to Health study comparing two Web-based interventions directed at health nutrition and physical activity reported small effects in randomly assigned individuals of -0.10 kg or -0.25 kg on body weight, none of them significant at long-term follow-up (27). Other studies reporting the results of non-Web-based intervention directed at improving physical health in sedentary obese elderly showed a mean body weight loss of 1.8 kg (11)] or a mean body weight loss -3.6% (3). In view of these results, our study showed a large effect on body weight. However, for studies primarily directed at body weight loss (including behavioural components other then physical activity) larger effects were seen compared to our study and most other studies directed at improving physical activity (25).

In the present study we showed in general a 1.2-fold to 2-fold larger effect in the successful participants compared to the entire intervention in most parameters. In a

dose-response analysis we observed that over tertiles of increasing objectively measured PA, there was an increase in beneficial effects of the intervention on body composition and metabolism. Of note, those with the lowest baseline PA level had the highest increase in PA level. The fact that there is a linear relationship between increase in objectively measured PA and beneficial changes in body composition and metabolism indicates that there is also a beneficial effect of the intervention in participants who do not reach the targeted PA goal. One interpretation may be that intervention programs should focus on how to increase the compliance of participants to the program and to set feasible PA goals leading to higher PA levels in general for all participants.
The present paper did not intend an analysis of the determinants of parameters that determine which factors predict which participants were successful in reaching the end goal of the study intervention. Such a determinant analysis will be performed in forthcoming studies and will address different research questions with the ultimate aim to better target different populations.

A drawback of our study is that we selected highly motivated participants who were able to use the Internet, leading to a population with a high educuation level. This hampers generalizability. Furthermore, we did not measure the food intake, which can be of great importance when studying the working mechanism, having a direct effect on energy balance and several of the metabolic health parameters. A strength of this study is that we objectively measured physical activity. Furthermore, although in general participants were overweight, our study population consisted of volunteers in which comorbidities were present, increasing the interpretation for the general elderly population. Furthermore, this study is unique in analysing the dose-response relationship of physical activity within the intervention group, leading to new insights for intervention programs. Finally, since it is a Web-based intervention the intervention is likely to have a better cost-benefit compared to face-to-face physical activity interventions.

In conclusion, 42% third of the intervention group had reached the end goal for daily PA, which was associated with a markedly better effect on metabolism compared to the effect in the entire intervention group. Findings demonstrate the large potential of Web-based interventions for improving health in the aging population by increasing PA, with likely improvement still to be sought in increasing the proportion of the population reaching the targeted end goal.

CHAPTER 7. DOSE-RESPONSE EFFECTS OF A WEB-BASED PHYSICAL ACTIVITY INTERVENTION

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